Atty. Dkt. 4448-9
110054503US/LEG/MFH

U.S. PATENT APPLICATION

Inventor(s): Roland Sixten Johansson

Invention: AN APPARATUS FOR EVALUATING MANUAL DEXTERITY

NIXON & VANDERHYE P.C.
ATTORNEYS AT LAW
1100 NORTH GLEBE ROAD, 8TH FLOOR
ARLINGTON, VIRGINIA 22201-4714
(703) 816-4000
Facsimile (703) 816-4100

829586

TITLE OF THE INVENTION

AN APPARATUS FOR EVALUATING MANUAL DEXTERITY

BACKGROUND OF THE INVENTION

[0001] The present invention relates to an apparatus for evaluating manual dexterity in humans and in particular to an apparatus for evaluating the manual dexterity of humans with an impaired nervous system and/or musculoskeletal system.

[0002] Manual dexterity of humans can provide useful information in relation to their nervous system and/or musculoskeletal system. This information is required for a variety of reasons ranging from pre-operative, post-operative and ongoing assessment of functional abnormalities in patients for adapting and optimising training protocols, to prognosis and diagnosis of patients. Additionally, evaluation of manual dexterity can provide valuable information for insurance companies for whom accurate assessment of the recovery of accident victims is vital to prevent against fraudulent claims.

[0003] A variety of apparatuses have been manufactured and a number of methods have been devised in order to assist medics and other interested parties with the complex technique of assessing and evaluating manual dexterity in humans. U.S. Patent No. 5,174,154 discloses an isometric force-measuring pinch meter having first and second opposed force-bearing surfaces. An incompressible, nonfluid material is positioned between the first and second surfaces and is capable of building up pressure in response to the application of force to the force-bearing surfaces. A pressure transducer is responsive to the pressure stored in the material for producing an output signal representative of the force. The apparatus is for use with either hand for measuring pinch strength and for ease of application of the fingers and thumb about the apparatus. It also removes any inaccuracies induced by misalignment of the thumb and fingers on the device itself.

[0004] U.S. Patent No. 4,674,330 discloses an apparatus for measurement of both the grip strength of a person's hand and the pinch strength of two digits of the hand. The apparatus comprises two parallel grip handles extending at right angles from a third member. The handles are rigidly fixed to the third member and have two

pairs of strain gauges to measure the force applied to the handles irrespective of where that force is applied. The ends of the handles terminate in flat portions to be used for measurement of pinch strength. Again, the apparatus is for use with either hand for measuring both grip strength and pinch strength. U.S. Patent No. 4,878,384 discloses a device for evaluating and measuring human sensory perception by measuring muscle force applied against a finger button and displaying a maximum muscle force. U.S. Patent No. 5,449,002 discloses an apparatus for recording the mechanical pressure applied by a patient recovering from injury or suffering from a disability during routine physical functions such as gripping by the hand. The apparatus utilises a technique known as biofeedback to help patients relearn functions or prevent complications that impede functions. German Patent No. DE 4,209,193 discloses an apparatus known as an Ergo graph for measuring the grip of a patients hand in addition to a method for measuring the personality changes in a patient as a result of brain damage suffered by the patient.

[0005] A substantial proportion of nervous system or musculoskeletal impairments are unilateral and therefore a person having such an impairment may have one hand in perfect working order. In order to fully asses the extent of the impairment of the nervous system and/or the musculoskeletal system it is essential to have a set of control data from a fully functional unimpaired hand to compare the data received from a damaged hand with.

[0006] All of the apparatuses and methods disclosed in the patent specifications discussed above are for operation by a single hand and designed to record forces applied by a subject in one direction only. However, manual dexterity and object manipulation is a three dimensional activity which often involves bimanual engagement. Any attempt to evaluate manual dexterity should take these facts into consideration.

[0007] Clearly there is a need for an improved apparatus and method for quantitatively assessing manual dexterity of a human in order to evaluate the level of impairment of the nervous system and the musculoskeletal system as a result of an accident or as a result of a mental or physical disability.

BRIEF SUMMARY OF THE INVENTION

[0008] Accordingly, there is provided an apparatus for evaluating manual dexterity and object manipulation in humans comprising a means for connecting two hands wherein each hand is capable of transmitting a force onto the other hand via the connecting means and the apparatus comprises a means for simultaneously measuring and recording omnidirectional forces applied by each hand. Torques applied by the subject can also be recorded.

[0009] In one aspect of the invention, one person holds the connecting means between both hands. The apparatus allows simultaneous measurement of the capacities of the left and the right hand. Thus, with unilateral impairments the contra lateral (unimpaired) hand will immediately serve as a reference.

[0010] In a further aspect of the invention, the connecting means is held by two people, with each person holding the apparatus by one hand. Beneficially, if one of the people, an experimenter holds the connecting means at one end and the second person, a subject holds the connecting means at the other end, both the experimenters hand and the subjects hand can be evaluated independently.

[0011] Preferably, the connecting means is provided by a hand-held unit. This removes the influence of all variables except gravity and forces applied by subjects holding the hand held unit.

[0012] Preferably, the apparatus further comprises a control unit in communication with the measuring and recording means for recording and analysing forces received by the measuring and recording means. On-line communication between the control unit and the measuring and recording means increases the functionality of the apparatus.

[0013] Preferably, the control unit is in communication with the measuring and recording means telemetrically. This allows the apparatus to take advantage of digital telemetric techniques that are available as silicon chips.

[0014] In another embodiment, the control unit and the measuring and recording means are physically connected by electrical cable.

[0015] Ideally, the control unit and the measuring and recording means are physically integrated into one unit.

[0016] Ideally, the control unit is provided by a computer and a variety of peripheral devices such as speakers and a display screen.

[0017] Preferably, the computer is configured by a customised control program. The control program is an essential feature of the invention providing the apparatus with on-line functionality.

[0018] Ideally, the hand-held unit comprises a pair of handles attachable about either end of a joining member wherein the joining member transmits forces between said handles.

[0019] In one embodiment, the handles are fixed to the joining member.

[0020] In another embodiment, the handles are rotatable about the longitudinal axis of the joining member.

[0021] Ideally, each handle has a pair of grip surfaces for receiving any of the digits of a person's hand. The primary purpose of the apparatus and the associated analysis procedure is the efficient quantitative assessment of the functionality of digits of the subjects' hands in terms of force coordination for grasp stability under different grasp loading conditions and the ability to symmetrically apply fingertip forces about opposite grip surfaces of the handles during precision manipulation. Thus, reduction in control of the digits as a result of both impairments in the nervous system and impairments in the musculoskeletal apparatus will be revealed.

[0022] In a preferred embodiment, the grip surfaces are provided by longitudinally extending hemi-cylindrical ridges co-axial with the longitudinal axis of the joining member when the handles are mounted on the joining member. This simplifies assessment of the subject's ability to choose advantageous contact points on the grip surfaces by focusing on their longitudinal dimension. Healthy subjects avoid applying asymmetric forces by opposing digits because it creates unnecessary internal forces within the handles (i.e., uneconomical tangential forces that, in turn, have to be matched by higher grip forces).

[0023] Preferably, the distance between the grip surfaces is in the range of 10 to 40 millimeters. This allows the apparatus to be used across a wide range of subjects including children and adults having a variety of hand sizes. One area of potential use for the apparatus is thus for following the ontogenetic development of sensorimotor functions. Today, the routine clinical methods that are used to identify children with sensorimotor impairments are very basic and provide little quantitative evaluation.

[0024] Preferably, the handles of the apparatus are equipped with transducers to measure omnidirectional forces generated by the subject at each of the grip surfaces. The transducers permit measurements of coordination between grip forces and tangential forces at each of the two grip surfaces. For each hand, the transducers measure the opposing grip forces applied in directions normal to the length axis of the hand held unit and the load force applied tangential to the grip surfaces, i.e. push/pull forces applied along the length axis of the hand held unit and twist forces (torques) applied and around this axis. The force tangential to the gripped surfaces at each digit is measured together with torques around the centre of grip force pressure. The total tangential load can be computed based on these measurements.

[0025] Ideally, the transducers measure internal forces due to asymmetric applications of the gripping forces produced by opposing digits at each grip surface along with measurements of the points of force pressure centres.

[0026] In a preferred embodiment, the handles are attachable about either end of the joining member. This reduces the complexity of the overall apparatus and reduces the number of parts to be designed and manufactured.

[0027] Preferably, the handles are interchangeable with handles having alternative geometries.

[0028] Preferably, handles having parallel, tapered and curved surfaces are used. Obtaining grip stability on different surface geometries requires changes in balance between the grip force and tangential force applied about the grip surfaces. Thus, sensory information about surface geometry is used to adjust the force balance. Grip stability implies that subjects apply grip forces large enough to avoid accidental slips, while at the same time excessive grip forces are avoided, which naturally may harm the apparatus, injure the hand or cause unnecessary muscle fatigue.

[0029] Concerning changes in surface geometry, a powerful variation is implemented by tapered grip surfaces. If the grip surfaces of the handles are tapered towards each other at the end of the handles distal from the joining member healthy subjects apply higher grip forces when they pull on the handle for maintenance of grip stability in comparison to parallel grip surfaces. With grip surfaces of the handles tapered towards one another at the end of the handles proximate to the joining member, stronger forces are required when applying push forces.

[0030] In a preferred embodiment, the geometry of each handle is adjustable by mechanical, electrical or other non-manual means.

[0031] In one embodiment, a shield is placed between the subject and the handles. This prevents the subject using their vision to adjust the balance required between grip-load force coordination, in particular when working with changes in the geometry of the grip surfaces. It is necessary to avoid visual cues when testing the capacity of the sensibility of the digits to mediate adaptation of the balance between the grip and load forces to variations in the surface geometry.

[0032] Preferably, the joining member comprises two sections and a coupling mounted there between.

[0033] In a preferred embodiment, the two sections are inter-engaged to allow compression and extension of the joining member along their longitudinal axis in response to push/pull forces applied by a subject and the coupling applies a predetermined biasing force opposing the compression and extension of the joining member.

[0034] In a preferred embodiment, the coupling is in communication with the computer and the biasing force applied by the coupling can be momentarily removed in response to a signal from the computer and subsequently reapplied. The coupling between a left and a right section of the joining member is temporarily broken and subsequently latched. A load rebound occurs when the coupling is latched. This transient load impact triggers automatic gripping force increases based on signals from sensors in the hand in a healthy subject. Results taken from this test can be used to obtain useful information in relation to the nervous system and the musculoskeletal system.

[0035] Preferably, the computer generates the signal at random times during the test. This will increase the likelihood of obtaining genuine responses from subjects and therefore improve the accuracy of the test.

[0036] Alternatively, the signal is generated by the computer in response to a predetermined time having elapsed from commencement of the test, in response to a certain force applied to the coupling by the subject or in response to a certain distance travelled by the two sections of the joining member as a result of a force applied by the subject.

[0037] Additionally, the computer generates signals providing information for subjects taking the test.

[0038] Preferably, the information includes a demonstration and instructions for the subject taking the test.

[0039] Ideally, the signals may be audible, visible or tangible. This facilitates people with visual and/or audio deficiencies.

[0040] Preferably, the signals include various target forces for subjects to aim for. This provides an element of control to the evaluation process and allows an experimenter to set limits for a subject to aim for.

[0041] In one embodiment, the signal is output as a visual display on a screen. This allows for efficient and interactive communication with the subject in terms of providing instructions for the desired actions.

[0042] In one embodiment, the screen is a freestanding unit located in front of the subject.

[0043] In a preferred embodiment, the screen is positioned on the joining member between the two handles. This helps to focus the subject's attention entirely on the hand-held unit. In another embodiment, the signal is output as an audible signal via speakers. This allows people with impaired vision or blindness to successfully operate the apparatus.

[0044] Preferably, the computer comprises a means for receiving and storing input forces measured by the transducers.

[0045] Ideally, the computer comprises a means for comparing the forces received with a set of control values which are input by the experimenter.

[0046] Preferably, the computer generates a signal informing the subject that they have successfully completed the current section of the test. This signal is only output after the comparison of current input forces with control values has been carried out and the input forces are acceptable for further processing. This removes the possibility of unsuccessful tests due to unusable data being collected thereby saving time and money.

[0047] In a particularly preferred embodiment, the computer instantaneously outputs a signal containing the values of current input tangential forces being received at the grip surfaces and being measured by the transducers to the subject either audibly, visually or tangibly thereby updating the subject on the progress being made.

[0048] In a still further aspect of the invention, the visual display includes a pre-test demonstration using graphical symbols or characters showing the subject what they are required to do.

[0049] Preferred embodiments of the invention will now be described with reference to the accompanying drawings and test procedure, which show and outline, by way of example only, one embodiment of an apparatus and method for evaluating manual dexterity in humans in accordance with the invention. In the drawings:

BRIEF DESCRIPTION OF THE DRAWINGS

[0050] Figure 1 is a schematic drawing showing an elevation view of the apparatus;

[0051] Figure 2 is a schematic end view of one handle of the apparatus;

[0052] Figure 3 is a schematic elevation view of a hand held unit including a display screen;

[0053] Figure 4 is a schematic drawing of a hand held unit showing a coupling;

[0054] Figure 5 is a schematic drawing of a hand held unit showing a shield;

[0055] Figure 6 is a schematic elevation view of a hand held unit having one combination of handles;

[0056] Figure 7 is a schematic elevation view of a hand held unit having another combination of handles;

[0057] Figure 8 is a schematic elevation view of a hand held unit having another combination of handles;

[0058] Figure 9 is a schematic elevation view of a hand held unit having a still further combination of handles;

[0059] Figure 10 is a representational graph showing the results of a test conducted using parallel and tapered grip surfaces; and

[0060] Figure 11 is a schematic drawing showing one possible visual display to be output on a display screen;

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0061] Referring to the drawings and initially to Figure 1 there is shown an apparatus for evaluating manual dexterity and object manipulation in humans

indicated generally by the reference numeral 1. The apparatus 1 comprises a hand held unit 2 and a control unit 3. The control unit 3 is connected to the hand held unit 2 by electrical cable 4. The hand held unit 2 comprises a pair of handles 5 and a joining member 6. The handle 5 on the left hand side of the unit 2 has parallel grip surfaces 7 and the handle 5 on the right hand side of the hand held unit 2 has tapered grip surfaces 8. Transducers (not shown) are fitted to the grip surfaces 7 and 8 and additionally on or about the connection between the handles 5 and the joining member 6. Straight and curved arrows indicate examples of directions of forces and torques measured by fitted transducers. The control unit 3 comprises a computer 9 having a monitor 10 and speakers (not shown).

[0062] Referring now to Figure 2, there is shown a handle 5 of the hand held unit 2. The grip surfaces 12 of the handle 5 are provided by longitudinally extending hemi-cylindrical ridges 11. The ridges 11 are co-axial with the longitudinal axis of the joining member 6 when the handle 5 is mounted on said member 6. The handle 5 is pinched on grip surfaces 12 between a thumb 13 and an index finger 14 of a subject's hand 15. The distance between grip surfaces 12 is typically between 10 mm and 40 mm. In Figure 3, there is shown a hand held unit 31 having a pair of handles 32, a joining member 33 and a display screen 34. The handles 32 have parallel grip surfaces 35 and the display screen 34 is mounted on the joining member 33 of the hand held unit 31.

[0063] Referring now to Figure 4, there is shown a hand held unit 41 having a pair of handles 42 and a joining member 43. The joining member 43 has two sections 44 and 45 and a coupling 46 mounted between the two sections 44 and 45. The two sections 44, 45 are inter-engaged to allow compression and extension of the hand held unit 41 about the longitudinal axis of the joining member 43. The coupling 46 is designed to oppose the extension and compression of the hand held unit 41 and is also designed to allow a momentary removal of the opposing force and subsequent latching. Figure 5 shows a further embodiment of the invention wherein a hand held unit 51 has a pair of handles 52, a joining member 53, a display screen 54 and a shield 55. In this example, the shield 55 is mounted between the hand held unit 51 and the display screen 54 in order to prevent a subject from seeing the shape of the handles 52 on the hand held unit 51.

[0064] Figures 6 to 9 each show a hand held unit indicated generally by the reference numeral 61. The units 61 each have a joining member 62 and a pair of handles with various geometries. Figure 6 shows a hand held unit 61 with both the left handle and the right handle having parallel grip surfaces 64. Figure 7 shows a hand held unit 61 with the left handle having grip surfaces 74 tapered at 30° to the horizontal and the right handle having parallel grip surfaces 75. Figure 8 shows a hand held unit 61 with the right handle having grip surfaces 84 tapered at 30° to the horizontal and the left handle having parallel grip surfaces 85. Figure 9 shows a hand held unit 61 with both the left handle and the right handle having grip surfaces 94 tapered at an angle of 30° to the horizontal.

[0065] Referring to the drawings and now to Figure 10 there is shown a representative graph of pull force on the x-axis versus grip force on the y-axis. Line 101 represents a handle with parallel grip surfaces and line 102 represents a handle with tapered grip surfaces. Finally, Figure 11 shows one possible visual display generated by the computer 9 when configured by the control program and output via a display screen 111. An image of an electronic stick-man 112 holding a hand held unit 113 demonstrates what a subject is required to do. A visual display of a scale 114 is marked with vertical lines 115 and displays force. This scale 114 shows a subject the zero force marker 116 and the target force marker 117 by highlighting the relevant line 115 along the scale 114. The dot 118 shows the current force. A target for maximum pull force 119 is located at the right end of the scale.

[0066] In use, a subject or an examiner starts a test by striking any key on a keyboard of the computer 9. This initiates the demonstration on the display screen 34, 54, 111 or initiates an audible demonstration. The audible demonstration includes a list of verbal instructions output via speakers connected to the computer 9 and is useful for a subject with impaired vision or blindness. When a visual demonstration is used, a pull or push prompt is displayed on the computer screen 34, 35, 111 and in response the stick man 112 stretches or compresses the electronic hand held unit 113 in order to show a subject the correct action to take in response to a specific prompt. Within the same display screen 34, 54, 111, the scale 114 shows the effect of the stick man 112 stretching or compressing the electronic units 113 by simultaneously moving the current force marker 118 between the zero force marker 116 and the target force marker 117.

[0067] Once a subject is satisfied with the demonstration, they can proceed with the test by striking any key on the keyboard of the computer 9. The hand held unit 2, 31, 41, 51, 61 is held by a subject by the grip surfaces 7, 8, 12, 35, 64, 74, 75, 84, 85 and 94 between digits of their hands. The subject then follows a list of prompts displayed on the display screen 34, 54, 111 or a list of verbal instructions output via speakers which are connected to the computer 9. The display also includes the scale 114 which shows the effect of the subject stretching or compressing the hand held unit 2, 31, 41, 51, 61 by simultaneously moving the current force marker 118 between the zero force marker 116 and the target force marker 117. The visual display may also include a prompt for the subject to maintain the target force for a predetermined period of time. Once the target force has been attained, the computer 9 monitors the quality of the data received from the transducers (not shown) comparing it with control data. The computer 9 outputs a signal to the display screen 34, 54, 111 informing the subject to release the applied force if the data received is acceptable. Alternatively, these prompts can be output via the speakers. The subject follows the audible or visual instructions until completion of the test. In order to prevent the subject using their vision to alter grip-load force co-ordination a shield 55 is placed between the hand held unit 2, 31, 41, 51, 61 and the subject for certain parts of the test.

[0068] The hand held unit 2, 31, 41, 51, 61 is grasped bimanually and manipulated according to a pre-defined (standardized) protocol. An automated test protocol combined with automated data analysis allows efficient assessment of the subject's manual status based on the data obtained from the force/torque transducers of units 2, 31, 41, 51 or 61.

[0069] There now follows a detailed description of an example of a test protocol and data analysis.

[0070] 1. The subject familiarizes themselves with the apparatus 1 by doing a few ramp-and-hold pull forces and push forces to certain target forces (e.g. +4 Newtons (N), -4N). Before the action, the task is demonstrated on the display screen 34, 54, 111 by the icon stickman 112 performing the task. The subject's task is to copy the demonstration.

[0071] 2. The subject performs a series of ramp-and-hold pull forces of different magnitudes according to the predetermined protocol (e.g., 1, 4, 2, 8

Newtons (N)) three times followed by a series of push forces (e.g. 4, 4, 4 N). These tests are repeated for the different geometric configurations of the handles, shown in the drawings. Quality control of the data occurs on-line and is dependent upon the subject maintaining the target push/pull force (within a predefined tolerance) for two seconds. In response to successful completion of the task by the subject, the target marker 118 on the display screen 34, 54, 111 is turned off. An audible signal indicating that this section of the test has been successfully completed could also be generated.

[0072] Analysis: The computer 9 configured by the control program automatically reads and stores the measured variables during a 2 second epoch while the subject maintains the target force. The coordination between grip force and the load at each hand (and at the level of the individual's digits) is automatically analyzed. The subject's capacity to scale the grip force with the load force and to adjust the balance between the grip force and load with changes in geometry of grip surfaces 7, 8, 12, 35, 64, 74, 75, 84, 85 and 94 is assessed for each hand.

[0073] 3. The subject makes sinusoidal pull forces at different frequencies. The amplitude (e.g. 4N with approximately +/-20% tolerance) is guided by the display screen 34, 54, 111. A metronome sound guides the pace. The frequency range to be explored is 0.5 - 3 Hz. Again, quality control of the data occurs on-line. Before changing to the next frequency, a certain number of cycles with an accepted amplitude and frequency are collected. (The grip surfaces 7, 12, 35, 64, 75, 85 are parallel on all handles.)

[0074] Analysis: The phase between grip force and the load is analysed; normally there is no phase lag, which indicates that the grip force predicts adequately the self-generated load forces (for grip stability). The depth of grip force modulation is assessed as a function of frequency; normally there is a steep decrease in the modulation with increased frequency, starting at about 1.5 - 2 Hz.

[0075] 4. The subject makes sinusoidal pull-push forces at different frequencies (0.5 - 1.5 Hz) and at constant push-pull amplitudes (e.g. -4N (push) to +4N (pull)). (The grip surfaces 7, 12, 35, 64, 75, 85 are parallel on all handles.) In this task, the absolute value of the tangential load increases and decreases with twice the frequency of the sinusoidal load. Normal subjects respond to this "frequency

doubling" by generating two grip force increases per load cycle i.e. the grip force predicts the actual load although it does not match the frequency of the load cycles.

[0076] Analysis: The phase between grip force and the absolute value of the load and the depth of grip force modulation is analyzed (cf. above). This analysis assesses the subject's ability to generalize the directional consequences of self-generated fingertip loads in terms of grip force requirements (and thus grip force predictions).

[0077] 5. The subject produces their maximum bimanual pull force. Normally, a subject's right hand is stronger than their left- yet subjects never allow the left hand to slip off the unit 2, 31, 41, 51, 61 during bimanual operations because the knowledge of their musculoskeletal system is incorporated as a control constraint in the neural networks of the brain. To assess asymmetries of force generating capacity by the two hands, the maximum grip force is assessed for each hand separately.

[0078] 6. Finally, by imposing the transient load impact at a few unpredictable points during the test protocol numbered 2 (see above) the reflex status of the reactive grip force control of the two hands is assessed. Normally, with two healthy hands, the load impact triggers automatic grip force increases at both hands with similar amplitudes and onset latencies.

[0079] The results of the tests provided the following information.

[0080] Impairment of sensory functions of the digits is reflected in:

[0081] 1. A weakened or lost capacity of the impaired hand to adjust the balance between the grip forces and the load forces in response to changes in geometry of the grip surfaces 7, 8, 12, 35, 64, 74, 75, 84, 85 and 94.

[0082] 2. With sensory impairment of one hand, the accompanying healthy hand also controls the grip-load force coordination of the numb hand. Likewise, the healthy hand uses strategies that reflect constraints imposed by the impaired hand during bimanual actions.

[0083] 3. The impaired hand generates increased internal forces upon the hand held unit 2, 31, 41, 51 or 61 due to asymmetric grip force applications at the opposing grip surfaces 7, 8, 12, 35, 64, 74, 75, 84, 85 and 94. This causes unnecessary/uneconomical load of the grasp.

[0084] Impairment of predictive control of grip forces is reflected in:

[0085] 1. A temporal mismatch between the grip and load force changes and is revealed during the test with sinusoidal load changes.

[0086] 2. A reduced modulation of grip forces with load force changes compared to healthy conditions.

[0087] Impairment of reactive control of grip forces is reflected in:

[0088] One or several of the following items revealed impaired reactive grip force control: (1) No response to the transient load impact. (2) A prolonged onset latency of the reactive grip force increases. (3) Smaller amplitudes than normal of the reactive grip force increases. With unilateral impairments, asymmetries between the hands in these respects are important.

[0089] Impairment of the brain's proprioceptive knowledge:

[0090] With impaired proprioceptive knowledge concerning one diseased hand the healthy contralateral hand shows incompetence in controlling its actions based on constraints imposed by the diseased hand during bimanual tasks. Impaired proprioceptive knowledge is assessed in the present protocol by an inability of the healthy hand to limit the application of pull force to the hand-held unit as to match the capacity of the companion diseased hand. This is critically revealed during the test of maximum voluntary bimanual pull along the hand-held unit 2, 31, 41, 51, 61. With proprioceptive knowledge the hand-held unit 2, 31, 41, 51, 61 does not slip at the diseased hand, whereas with loss of proprioceptive knowledge the unit 2, 31, 41, 51, 61 slips from the subjects grip.